A STUDY ON THE DETERMINATION OF SEX,AGE AND STATURE FROM THE STERNUM

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Certificate

This is to certify that the study entitled “A Study on the Determination of Sex,Age and Stature from the sternum” has been done by Dr.C.Manoharan, under our direct guidance and supervision in partial fulfilment of the regulations for M.D. Degree (Forensic Medicine) of The Tamilnadu Dr.M.G.R. University , Chennai.

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INTRODUCTION

Identification connotes the determination or establishment of the individuality of a person living or dead.

Identification of an Individual whether living or dead is one of the most crucial tasks in medico-legal practice. The experts always face problems in identifying whether skeletal remains are of human origin or not, as well as estimation of correct sex, age, stature etc. It is an exacting, painstaking and time consuming process that requires considerable scientific knowledge and expertise.

The services of forensic medicine experts are sought in establishing the identity of the dead, especially in mass disasters like fires, explosions, ship wrecks, air crash and railway accidents. Extreme mutilation, advanced decomposition, skeletal and fragmentary remains, make the process more confounding and complicated. Therefore, given the complexities of such situations, it is highly essential that medico-legal men should be well versed in various aspects of identity establishment.

Most of the time forensic medicine specialists have to mainly depend upon the bones for establishing the identity. They are often required to estimate sex, age and stature of a person from dismembered body parts and bones.

Sex, age and stature are very important criteria in establishing the identity of an individual. Other findings such as racial features, moles, scars professional

marks and colour/complexion which are fairly permanent throughout life may also be useful in establishing the identity of a person.

The determination of sex is an important criterion in personal identity. This is fairly easy if the primary and secondary sexual characters are intact . But in cases of intersexes and concealed sex and when only few skeletal remains are available, a cautious scientific approach is required to establish the sex of the individual. Determination of the sex from the skeletal remains is an accepted procedure.

Estimation of age in elderly person is often required in medico legal practice. Estimation of age in elderly person is comparatively more difficult than in young persons. The young individual has various factors for age estimation such as physical and morphological features, eruption of teeth, ossification activities and growth of bones which help in establishing the age with utmost accuracy. On the contrary, the elderly persons have very few identifying factors like fusion of skull sutures, changes that occur in the pubic symphysis, degenerative changes and application of Gustafson's formula (based on the ageing and decaying changes of teeth). Age estimation in elderly person has limitations due to paucity of anatomical factors.

Skeletal growth changes are the most important criteria for age estimation. Study of changes in skeleton with respect to age, serves as a reliable and time honoured method in medico-legal work. Biological phenomena other than skeletal changes are subject to wide variation.

Stature of an individual is subject to psychological, environmental, genetic and nutritional factors.

Anyhow, length of different body parts bears more or less some constant relationship with the body length. Determination of stature is an easy task if a complete body or the entire skeleton is found. When only some parts of the body (or) if a skeleton is available, it is necessary to have different formulae for determination of stature from their osteometric measurements.

The present study is an earnest attempt to assess the sex, age and stature of an individual from one of the skeletal remains, namely the STERNUM which is one of the superficial bones, and is spared even in a highly decomposed body. Moreover, it is a bone which can be easily procured from cadavers, without the slightest damage during a routine autopsy procedure. So considering these factors, study of the sternum has been selected as an identifying unit of sex,age and stature.

OBJECTIVES

- Determination of sex of an individual from the sternum.
- Determination of age of an individual from the sternum.
- Determination of stature of an individual from the sternum.
- To correlate the findings of the present study with previous similar studies in this aspect.

REVIEW OF LITERATURE ANATOMY

The sternum or breast bone is an elongated nearly flat bone likened to a broad sword.[1] It is confined to land vertebrates, aquatic animals like seals and is absent in fish[2]

It lies in the midline of the anterior wall of the thorax and extends from the root of the neck into the abdominal wall. It can be felt through the skin in its whole extent[2].

Parts and features

The sternum consists of three parts from above downwards - the manubrium, body and the xiphoid process. The manubrium and body meet at an angle-the sternal angle. The sternal angle is felt through the skin as a transverse ridge.

The sternum slopes down and slightly forwards. It is convex in front, concave behind, broadest at the junction with the first costal cartilages. Then it narrows at the manubriosternal joint and again it widens to its articulation with the fifth costal cartilages and narrows once again below this.

Manubrium sterni or prosternum

Its anterior surface is smooth, convex transversely and concave vertically. Its posterior surface is concave and smooth. The superior border is thick with a central jugular or suprasternal notch between the two oval fossae which are

directed upward and posterolaterally for articulation with the sternal ends of clavicles. The sternothyroid and sternohyoid muscles are attached medial to these fossae on the deep surface of the manubrium. The sternomastoid is attached to the upper lateral part of the front of the manubrium and the pectoralis major to the lateral part of front of manubrium. The lateral borders of manubrium articulate with the first and second costal cartilages.

Body or Mesosternum or Corpus Sternum

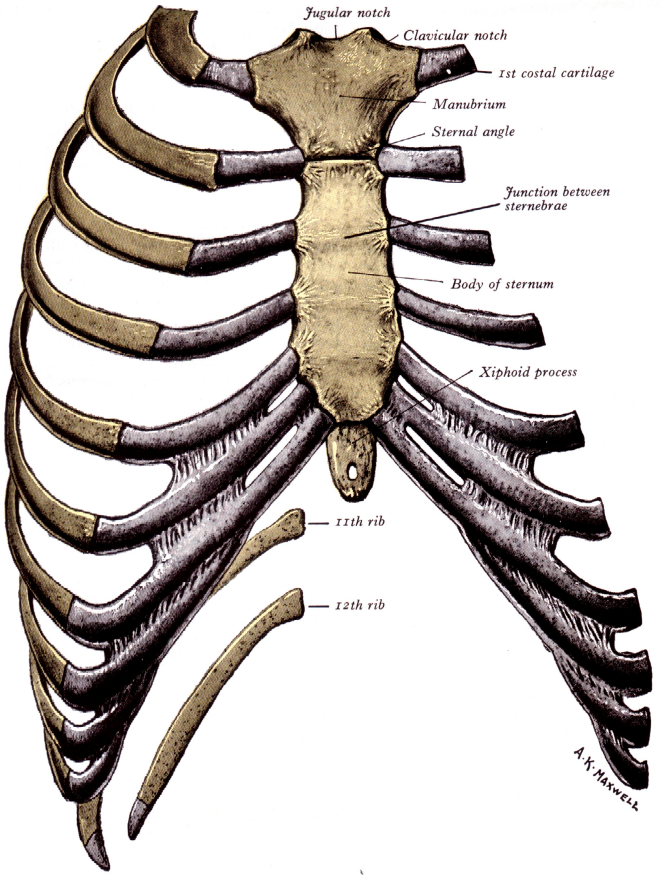
Consists of four sternebrae. Its anterior surface is nearly flat, faces slightly upwards and has three variable ridges at the levels of fusion of its four sternebrae. The posterior surface is slightly concave, also displays three less distinctive transverse lines. The oval upper end articulates with the manubrium to form the manubriosternal joint at the level of the sternal angle. The lower end is narrow and continuous with the xiphoid process.

The manubriosternal joint plays an important part in the mechanism of respiration, because it allows the body of the sternum to move forwards and backwards like a door on a hinge eventhough the manubrium remains still. It is a replica of the symphysis pubis and is similar in structure to the joints between the bodies of the vertebrae. All the joints lie in the median plane. They are symphyses that are two bony surfaces are lined with hyaline cartilage, are united by fibrocartilage and are covered with fibrous membrane. The manubriosternal joint may be lacking in some cases, its place being taken by a joint between 1st and 2nd sternebrae. The sternal angle is then situated halfway down the sternum.

On each lateral border, at the superior angle of the body of sternum, there is a small notch which articulates with the second costal cartilage, below this, four costal notches articulate with third to sixth costal cartilages, the inferior angle has a small facet, which with the xiphoid process receives the seventh costal cartilage.

Xiphoid process or metasternum

It is the smallest and most variable sternal element. It may be broad and thin, pointed, bifid, perforated, curved or deflected. It is continuous with the lower end of mesosternum forming the xiphisternal joint. Anterior to its superolateral edges are demifacets for the parts of the 7th costal cartilage. The diaphragm is attached to the deep surface of the xiphoid process and the rectus abdominis muscle to its outer surface.



Structure of the Sternum

Contains highly vascular, trabecular bone enclosed by a compact layer which is thickest in the manubrium between clavicular notches. The medulla contains red bone marrow. It is used to obtain samples of red marrow by sternal puncture. The bone is supplied by the internal thoracic artery [2].

Ossification

The sternum is formed by the fusion of two cartilaginous sternal plates flanking the median plane. Arrangement and number of ossification centres vary in relation to completeness and time of fusion of sternal plates and to the width of the adult bone.[3] The manubrium is ossified from one to three centres appearing in fifth foetal month, and the first and second sternebrae usually from single centres about the same time. Centres in third and fourth sternebrae are commonly paired and appear in fifth and sixth months respectively, but one of either pair may be delayed until seventh or even eight month, the fourth strenebral centre may be absent. The xiphoid process begins to ossify in the third year or later.

Incomplete fusion of double centres in the sternebrae results in formation of sternal foramina in the adult sternum. These are known as "Bullet Holes"[4].

Sex determination:

The necessity and difficulty of sex determination arises when decomposition of bodies has advanced to such an extent that external and internal sexual organs have disappeared. The same problem is there when only

portions of a body are available for examination.

As a general rule, definitive sexual traits in the skeleton do not manifest until after the full achievement of secondary sex traits that appear during puberty. The dividing line between immaturity and maturity is some where around 15 to18 years.[11]

Recognizable sex difference do not appear until after puberty i.e. during the afore mentioned period. Up to that time skeletons of the two sexes differ only in size.[16]

The determination of sex by an examination of the skeleton is based mainly upon the appearances of pelvis, sternum, the skull and long bones.[16]

The accuracy of sexing skeletal remains is as follows (According to Krogman)[11]

- Whole skeleton - 100%
- Pelvis alone - 95%
- Skull alone - 90%
- Long bones alone - 80%
- Pelvis and skull - 98%
- Long bones plus pelvis- 98%

According to Iordanidis (1961)

The skull and femur - 97.35%

The coccyx and sacrum - 97.18%

The coccyx	-	92.25%
The complete skull	-	91.38%
The skull without mandible	-	86.29%
The sternum	-	80.18%
The scapula	-	61.72%
The sacrum	-	41.10%
The femur	-	39.64%
The atlas and axis	-	31.18%
The clavicle	-	28.08%
The mandible	-	26.24%
The humerus	-	21.08%
The radius and ulna	-	18.62%
The calcaneum	-	14.72%
The astragalus	-	13.36%

According to St.Louis,

77% accuracy was obtained by simple inspection using the skull and the lower jaw; with the whole skeleton, the percentage of accuracy rose to 94%; for other parts alone except skull and pelvis, the accuracy was 50 to 70%.

Study of sternum as an individual parameter for determination of sex has been attempted by various workers. First recorded data is from Wenzel (1788). He described that the mesosternum is proportionally longer in males than the females but the manubrium in two sexes is almost equal in length.[51]

Sternum as an indicator of sex may be employed under circumstances where the more reliable criterions of the pelvic measurements are missing.[41]

A manubrium: body length ratio is 49:100 in males and 52:100 in females. (49 or below- males and 52 or above – females). (Dwight)[11]

Mean length of manubrium in males is 52.0mm whereas in females it is 47.0mm. Mean length of corpus sternum in males is 106.0mm, in females it is 89.0mm (Dwight-1881).[56]

Mean length of manubrium in males is 53.7mm whereas in females it is 49.4mm. Mean length of corpus sternum in males is 110.4mm and 91.9mm in females (Dwight-1890).[56]

Manubrium of the female sternum exceeds half of the length of the body while the body in males is at least twice as long as the manubrium.[42,62]

A maximal corpal length of over 110mm is in favour of a male sternum, while a maximal corpal length under 85mm indicates as to a female sternum. (Hintzsche).[11]

The sternal body in males is generally at least twice the length of the manubrium, while in females; manubrial length is nearly always greater than half the length of the sternal body.[43]

A sternal index is calculated based on the relative sizes of the manubrium and the body of the sternum, expressed as:

$$\frac{\text{Length of manubrium}}{\text{Length of body}} \times 100$$

The average index thus calculated, translates into the following values: 46.2 for males and 54.3 for females. [44]

Ashley has formulated the “136 rule” on East Africans which was applicable to 77.6% of male and 84.6% of female sterna.[61] He also found the “149 rule”, which says that if the combined midline length of manubrium and body of sternum equals or exceeds 149mm, the sternum is probably masculine; if less than 149mm, probably feminine. it has been estimated that by this rule, accuracy is obtainable in 80 percent of cases. But the drawback with this rule is that it was deduced after a study of sterna from European subjects, hence its applicability lies confined to the European race only. [3,45,77].

A study on Africans by some authors, reveals that the width of the manubrium ranged from 15 to 45mm in both sexes, With in this range the overlap of the sexes were from 26 to 38mm (Thieme and schull- 1957).[56]

The mesosternum was longer and narrower in males than in females (paterson).[57]

According to “Hyrtls’s law”, the ratio between the length of the manubrium and that of the mesosternum is more than 1:2 in case of women and less in men.[60]

The body of the sternum in females is less than twice the length of the manubrium while in males it is more than twice the length, but part of the difference is due to the fact that the male manubrium is on the whole somewhat smaller proportionately than that of females. [2,16, 36,37,38,76]

The mean length of the mesosternum is 110mm in males and 90mm in females with the difference of 20mm (Strauch).[58]

The body of the sternum in males is relatively broader in relation to sternal length. [3,46]

A sample of Native American sterna had been examined and it was found out that if the combined length of the manubrium and corpus sternii is greater than 140mm, the individual was estimated to be male. If the same measurement was less than 131mm, the individual was estimated to be female.131-140 mm was equivocal. Using this combined approach, the sternum of 72% of males and 62% of females could be sexed with 100% accuracy. The mesosternal length alone could be correctly sexed for 50% of males and 30% of females (JIT & Associates).[11,41]

Regarding mean length of manubrium, One author got 57.8mm for Males and 46.7mm for females. The combined length of manubrium and body of

sternum was 164.1mm in males and 141.3mm in females (Dwight).[53]

The manubrium is somewhat smaller in males, while bigger in females.[36,37,38,47,76]

A study conducted in adult Americans showed that no male manubrium and corpus sternii measured less than 121mm and no female measured greater than 173mm (John H.Stewert & F.Maccormick). [11,48,50]

On analysis of " Hyrtl's law index", the value was found to be greater than 50 in females and the opposite for males. In males, the range was in between 31-65 (average 51) and in females, range between 43-88(average 69) (JIT & Associates).[11]

Indian Studies

A study of 400 adult North Indian Sterna (312 male and 88 females) obtained from medico-legal postmortems was made.[49] If the combined length of the manubrium and mesosternum was more than 140mm, the sternum was male and if less than 131 mm it was female. No opinion could be given if the length was between 131 and 140mm. By this measurement 72.12% of males and 62.50% of females sterna could be sexed with 100% accuracy. The length of the mesosternum alone could also determine the sex correctly in 50.32% of male and 29.55% of female specimens. However it was concluded that the length of the manubrium and the manubrium corpus index were not useful in sexing a given sternum. By using multivariate analysis the probability of correctly identifying the

sex of a sternum was over 85% (JIT.I, Kulkarni.M).[49]

In another study of 100 adult North Indian sterna (56 males and 44 females), if the length of the manubrium is less than 33mm then it is of a female, if it exceeds 63mm, its of a male.

If the length of the body of sternum is less than 48mm, then it is of female. If it is more than 106mm, then it is of male. If the combined length of sternum is less then 92mm, then it is of female, where as if it exceeds, 161mm it is of male (GAUTAM, R.S.Shah). [52]

A sternum showing a midline length of body of less than 66.70mm suggested female sex and that measuring above 89.85 indicated males. Sternal index of 44 or less indicated male and above 65.45 females. Total length of manubrium and body of sternum, if this was 136.83mm or above the sternum could belong to a male and if 124.58mm or less it could belong to a female.[40]

The measurements of north Indian sterna indicated, if the combined length of manubrium and body is 140mm (or) greater, it is of male and 130mm or less, it is of female. Their indecisive range was 131-140mm. By these criteria, 72% of males and 63% of females could be sexed with 100% accuracy.[59]

A study conducted on 143 adults (96 males and 47 females) in Marathwada region by some authors who have formulated “The 129 rule” as similar to Ashley’s rule, by this 91.66 of male and 82.97% of female sterna could

be identified correctly. The length of mesosternum distinguished 69.80% male and 76.60% female sterna and by the combined length of manubrium and body, 38.54% of male and 57.45% female sterna could be sexed correctly. [62]

The conclusions of the study carried out in Thiruvanandapuram are as follows[67].

- We could categorize an unknown skeleton as male if the :
    1. Length of manubrium is more than 52mm.
    2. Length of body of sternum is more than 98mm.
    3. Breadth of manubrium is more than 59mm.
    4. Breadth of body of sternum is more than 40mm.
    5. Total length of sternum is more than 148mm.

If sternal index is more than 64 it could be a female; the values below which could be either a male or a female.

Age determination

Determination of age is a time honoured problem in medicolegal practice. Different methods have been adapted for determining the age and skeletal growth changes are the most important among them.

Skeletal growth changes are orchestrated by a complicated interplay of genetic, environmental and cultural factors.[5] Human biology is simply not amenable to the precision of pure or exact science. In other words, it is not possible to formulate a uniform standard data based on skeletal changes.[6] Countable differences are noticed in the appearance and fusion of ossification centres depending on race, geographic distribution, sex, food habits, nutritional

status, infectious diseases, physical activity, hormonal and metabolic disorders.[7] Growth changes in the skeleton, although a reliable basis for estimation of age, do not permit an exact determination, but only within a range.

The search for a method to determine the actual age of the skeleton at the time of death was started in the last century by anthropologists.

The first method used by anthropologists for age determination was the closure of skull sutures.[8,9]

Based on this method a "closure formula" was evolved for a given skull.[6] Studies showed that endocranial suture closure was a more reliable age indicator since ectocranial sutures frequently showed lapsed or incomplete union.[10]

Estimation of age of any dead individual gauged only on the degree of closure of vault sutures is a hazardous and unreliable process.[9,11]

Other regions studied

1. Pubic symphysis
2. Sternum
3. Ribs

A number of methods for skeletal age determination have been described, but the choice of an appropriate technique depends on the age at death, state of the remains and preference of the examiner.[12]

Up to the age of 25 years, age can be determined primarily from eruption of teeth, appearance of ossification centres and epiphyseal union.

I. Dentition and Age

An opinion about the age based on the examination of teeth is likely to be fairly accurate upto the age of about 25 years, but age diagnosis at later years is liable to considerable error.[13]

Gustafson has shown that microscopic examination of teeth is somewhat helpful in estimating age between 25-60 years. He explained that age of an adult can be assessed by noting the changes as regards to attrition, periodontosis. Secondary dentine deposition, cementum apposition, root resorption and transparency of root. In order to make it accurate a standard curve was used. Age was calculated from the formula y=11.43 + 4.56 x, drawn from the regression line where y is the age and x is the total points. The error of estimation was found to be ± 3.63[14,15].

In the Indian studies by Dr.Pillai and Dr. Ramachandran using Gustafson's methods the regression equation was y=5.34x -4.08, where x is the total points.[23] In a same type of study by Dr V.T.Augusthy, all the parameters except root resorption showed maximum correlation. The maximum correlation was found to be in females. Overall standard error was ± 6.42 years.

II. Study on pubic symphysis

Many early and late studies are there on the progressive morphological

changes on the face of the pubic symphysis.[16,17,18,19,20]

The symphyseal surface of pubic bone undergoes regular metamorphosis from puberty onwards. The pubic symphyseal surface when considered as a modified diaphyseo-epiphyseal plane, may be expected to show metamorphosis.[16,18] The phase analysis technique for age determination was developed by noting 9 bony features. There was not much role for sex in age changes of the pubic symphysis. But there are deformities of the dorsal border in some females believed to reflect damage from child bearing.[16] So it is well to be cautious in applying male pubic standards to females.[20] Moreover this phase analysis method tends to overage some persons and could not account for variability.[16]

There is another related system known as component analysis, requiring formulation of the changes according to 6 stages (0-5) in each of 3 components.[21]

Inter observer error can occur in component analysis technique.[20] Still the accuracy of component analysis has not been seriously challenged. The major criticism of the component analysis system is that it is rather complicated to use, while phase analysis is easier to learn and more convenient for field work.[19]

Although the component analysis method works well, it was not intended to be utilized for female material since the method was based on study of males only.[22] It was found out that the female standard yielded better results than the male standard in ageing by using os pubis.

A recent study was conducted in Kerala to develop a standard for determination of pubic age in Keralites.[19] The important conclusions of this study were, as follows:

a. Reliability of determination of age based on the changes of pubic symphyseal surface is better than that of other methods.
b. Reliability is more in females.
c. In males 82% of cases could be correctly predicted with an average of ± 2.10 years whereas 90.24% of females could be correctly predicted using the standard of Gilbert and Mckern, with an average error of ±2.25years.

III. Study on ribs

By studying the head and tubercle of ribs, it was observed that ribs unite completely after the age of 22 years. Calcification of first costal cartilage in American Whites and Negroes was studied by Michelson. Mineralisation of costal cartilages was also considered as an indicator of age.[23]

Phase method: This study was on the age related metamorphosis in the costochondral area of the 4th rib.[24] Based on these changes the specimens were separated into nine groups (phases 0 through 8). The distribution of specimens into phases was based on the changes noted in the form, shape, texture and overall quality of the sternal end of the rib. Such changes were not seen until after 16 years.

Conclusions of the work are as follows:

a. Sternal extremity of rib is suitable for estimation of age in both sexes and the phase method is a viable technique for it.
b. In both sexes, morphological changes were found to begin only after the age of 16 years.
c. In males, the mean age was found to increase as the phases progressed.
d. In females, eventhough the sequence of events are the same, characteristic changes ascribed to each phase were found to develop early.

IV. Age determination from histology of long bones:

Age can be determined from histology of sections from long bones. The actual number of osteons, fragments of old osteons and non Haversian canals present in four anatomically separate one hundred power microscopic fields in the outer third of cortex of femur, tibia or fibula was counted. The average value gave a representative figure. The error noted with actual age was ± 5 years, when two or more bones from the same individual were used. The limitations of this study are that the accuracy and reliability are limited to major long bones. Anything that destroys a substantial part of the outer surface of the bone will make it unsuitable for microscopic age determination.

A similar study from Northern Kerala had shown that it is of little value for those above 50 years, but most useful for 10-50 years age group.[23] In another study it was shown that there is a good significance between the number of osteons and age irrespective of the sex. But these relations were relatively insignificant in females. It was also found out that this method is of little value for

those above 50 years but most useful for the 20-50 years of age group.[26]

V. **Age changes in scapula and vertebrae were also studied**.

VI. Studies on sternum

Dwight in his study stated that union of body elements of sternum was complete by around 20 years, but union of body with manubrium and xiphoid process were extremely variable.[11,53]

An American study on the manubrio-corporal union on Whites and Negroes (742 males and 135 females) whose age varied from 30 to 80 years, showed 10% incidence of union.[27]

Xiphisternum unites with the body by about 40-50 years of life, union between manubrium and body may be seen in advanced life.[29]

Body segments fuse with one another from the 6th to the 25th year.[28]

The xiphoid process does not join the body until middle age. The manubrium should not fuse until old age is reached. The remainder joins in sequence from below in childhood, at puberty and at 21 years.[3]

Roentgenological studies have shown that fourth and third sternebrae fuse between 4 and 8 years, second and first between 12 and 25 years, first piece of body and manubrium in old age. At the base of the sternal body there is a cartilage (Xiphoid) which may or may not calcify. [29]

Disappearance of the manubriosternal joint may occur in the period from 50 years to death, but this has been observed to be cartilaginous even in a centenerian.[30]

In a study conducted by Mckern and Stewart in 1957 in 368 Korean War dead, the fusion of component segments of sternum in males of age 17 to 50 years was found to be completed in most cases by 22 to 23 years. Rarely the upper most segments was found to be separated as late as 27 years.[11]

Sternebrae fuse with each other from below upwards during adolescence. The body of sternum thus fused into one plate, normally never fuses with the manubrium even in advanced old age.[31]

Certain other literature had shown that the fusion of sternebrae took place from below upwards about 15th, 20th, and 25th year. The xiphisternal joint fuses in about the middle of life.[32]

One author is of the opinion that if the three parts of the sternum are united by bone, the age of the individual could be above 35 years.[33]

The body pieces unite to form a single bone by the age of 25. Manubriosternal joint frequently ossifies after the age of 40.[34]

The union between 3rd and 4th segments takes place soon after puberty

and between 1st, 2nd and 3rd between puberty and 25th year[35].

Certain authors state that the four middle pieces which constitute the body, fuse with one another from below upwards between 14 and 25 years. The xiphoid unites with the body at about 40th year, while manubrium rarely unites with the body except in old age.[36,37,38,76,77]

According to one author, the manubrium fuses with the body at the age of 60 or still late.[45]

Indian studies

The pattern of sternal fusion in North West India has been studied.[39] It was observed that all specimens exhibited complete fusion between 3rd and 4th segments in 15-17 years age group; fusion between 2nd and 3rd segments occurred in males over 25 years and in females over 30 years; first and second segments showed complete fusion in males over 60 years and in females over 30 years. A mesosternum showing fusion of all the sternebrae must be from a subject over 16 years if male and over 18 years if female.

The fusion of manubrium with body of sternum occurs at very old age (55-60yrs).[63]

Complete fusion of mesosternum with manubrium does not take place earlier than 21 yrs of age in both males & females. [55]

For the indigenous people of Manipur, the regression formula i.e y= 29 + 10x (male) and y = 30 + 12x(female) with a standard deviation of ± 8 (for male) and ± 7.1 (for females) can be used in determination of age from the degree of fusion of Manubrio-mesosternal joint. If the sex of the Individual is not known, the regression formula obtained from the study of male and female combined i.e. y = 29 + 11x with a standard deviation of ± 8.3 may be used.[66]

The fusion of third and fourth sternebrae becomes completed at puberty. The fusion between first, second and third occur by the age of 25 years. The fusion of xiphoid process with the body of sternum starts after 30 years. In most of the cases the fusion is completed after the age of 50 years. The fusion of the manubrium with the body of sternum begins after the age of 40 years. Complete fusion occurs after the age of 50 years.[52]

A study was carried out on the sterni obtained from 150 cadavers (120 males and 30 females) concluding that, Fusion of body segments occured from below upwards. Minimum age for fusion between 3rd and 4th segments was 13 years and between 2nd and 3rd segments 17 years. Complete fusion of body of sternum indicated a minimum age of 19 years. Fusion of xiphoid with body occurred in between 22 – 44 years. Incidence of fusion of manubrium with body is very low and this change is not helpful in age determination.[40]

The conclusions of a study carried out in Tiruvanandapuram are as follows [67]

1. Fusion between 3rd and 4th sternebrae could start even below 10 years.

2. The individual is certainly above 10 years if 2nd and 3rd or 1st and 2nd sternebrae are fused.
3. Minimum age of the individual could be 19 years if all the segments of the body of sternum are fused.
4. Age of union of manubrium and xiphoid process with the body of sternum are rather unpredictable.

Table 1 : Various studies on fusion of sternum

Name of author	Year	Between sternebrase	Between Xiphoid & body	
Dwight	1962	Complete by 20 years	Extremely variable	Extremel
Lyons	1933	-	-	10% incid
Douglas J.A.Kerr	1954	6th to the 25th year	40 to 50 years	In advanc
Ashley	1956	At childhood, puberty and at 21years	Middle age	Old age
Girdany and Golden	1952	Fourth and third sternebrae fuse between 4 and 8 years, second anf first between 12 and 25 years	Old age	Old age
Keith Simpson	1953			50 years
R.J.Last	1970	Fusion from below upwards during adolescence		Never fus
J.C.Boileau Grant	1958	From below upwards about the 15th , 20th and 25th years	Middle of life	
Sydney smith	1956	If the manubrium xiphoid and body of sternum are united by bone , the age could be above 35 years		
W.J.Hamilton	1976	25 years		After 40
P.V.Guharaj	1982	3rd and 4th segments unite after puberty, 1st 2nd and 3rd between puberty and 25th year	40 years	Hardly ur
Modi	1988	From below upwards between 14 and 25 years	40 years	Hardly ur
Parikh.C.K	1990	From below upwards between 14 and 25 years	40 years	Hardly ur
M.K.R.Krishnan	1971	From below upwards between 14 and 25 years	40 years	Hardly ur
India studies				
Jit I and Kaur.H	1989	3rd and 4th segments during 15-17, 2nd and 3rd segments: males - over 25 years femalss- over 30 years 1st and 2nd segments: males - over 60 years female - over 30 years		
Studies in Kerala M N Vijayan	1982	Minimum age for fusion a. Between 3rd and 4th segments was 13 years b.Between 2nd and 3rd segments 17 years c.For complete fusion of body 19 years	22-44 years	Incidence

Determination of Stature:

Determination of stature becomes very easy if a complete body is found. It is very difficult when only some parts of the body are available. At that time we

need to have different formulae for determination of stature.

The most accurate estimates of stature can be obtained when the equation applied to the unknown had been derived from a representative sample of the population of the same sex, race and geographical area to which the unknown is believed to belong. [70,71]

There are so many variations in the stature of the same individual.[77]

Stature is more:

- It is maximum between 20 and 25years of age of a person.
- It is more during morning hours of the day.
- It is more in the recumbent position (1-3cm).
- It is more in dead bodies during the stage of primary relaxation (upto 1.5cm in male and 2 cm in female).

Stature is less:

- After the age of 25 years, it decreases about 1mm per year.
- Malnutrition and changes in the intervertebral disc in old age reduce the stature.
- During the evening hours, the stature of a person may be about 1.5cm les than what it is during the morning hours. This is due to decreased elasticity and increased tonicity of the vertebral muscles in the evening hours.
- In a dead body, the length reduces during the stage of rigormortis.

The stature is obtained by

- ❖ Measuring the head to foot length.
- ❖ The length between the tip of the middle fingers of the outstretched hands gives the approximate stature of a normal individual.
- ❖ Stature is usually twice the length from vertex to the tip of symphysis pubis.
- ❖ Twice the length of one arm added to 34cms for the clavicles (15+15cm) and the sternum (4cm) gives the stature.
- ❖ The length from the sternal notch to the symphysis pubis is 1/3rd of the stature.
- ❖ The length of forearm from the tip of middle finger to the tip of the olecranon is equal to 5/19th of stature.
- ❖ The height of the head measures by the vertical distance from the top of the head to the tip of the chin is about 1/8th of stature.
- ❖ If the length of the entire skeleton is known, adding 2 to 3cm for the soft parts gives the stature.
- ❖ From the length of a long bone, stature of an individual can be calculated as per rule of thumb i.e.
    - Length of humerus represents 20% of stature.
    - Length of femur represents 27% of stature.
    - Length of tibia represents 22% of stature.
    - Length of spine represents 35% of stature
    - Length of clavicle represents 8 % of stature.[68]

Many workers like Pearson(1899), Pan(1924), Stevenson(1929), Nat(1931), Mendes Correa(1932), Breitinger(1937), Siddiqui and Shah (1944),

Telka (1950), Dupertius & Hadden (1951), Trotter & Glesser (1952), Singh & Sohal (1952), Oliver& Pineau (1958), Allbrook (1961), Oliver (1969), Badkur (1985), banerjee *et al*(1944), Nath & Badkur (1999) etc. have studied long bones of different persons from different geographical areas and derived different formulae for determination of stature.[75]

Some authors from Imphal, have studied 150 sterna, (100 males and 50 females) and derived some regression formulae as shown in the table:

Study Group	**Regression Formula**	**Standard Error of estimate**
Males	Y=1502 + 1.4X	± 6.0
Females	Y= 1506 + 0.16X	± 4.8
Males + Females	Y= 1406 + 2.34X	± 7.0
Co-efficient of Correlation :	Male = 0.4 Female = 0.3	

The standard error of estimate is ± 6 cm in males and ± 4.8 cm in females. But it becomes ± 7cm, when the regression formula obtained from the study of males & females should not be used as far as possible as the range of error is wider.[73]

MATERIALS AND METHODS

This chapter describes the study design, setting, sample size, source population, inclusion and exclusion criteria, procedure of dissection, technique of preparing of specimens, osteometric parameters used for analysis and the method adopted for analysis.

Study design

Cross sectional study

Setting

Department of Forensic Medicine, Medical College, Tirunelveli.

Sample Size

100 sterna collected during medico-legal autopsy.

Source population

Dead bodies brought for autopsy to the Mortuary wing of Department of Forensic Medicine during the period from June 2004 to June 2006.

Inclusion criteria

Sterna collected from 100 documented medico-legal autopsies with established identity.

Exclusion criteria

- Fracture of sternum
- Unknown dead bodies

- ❖ Cases where exact age is not known
- ❖ Diseased and deformed bones

Procedure of the removal of the sternum

The body is place in the supine position, with the arms by the sides of the body.

Y-shaped incision: A Y – Shaped incision is made on the front of the body, which begins at a point near the acromio-clavicular joint. It extends down below the breast and across to the xiphoid process.

A similar incision is carried out on the opposite side of the body. From the xiphoid process, the incision is carried downwards to the symphysis pubis.

Modified Y-shaped incision: An incision is made in the midline from suprasternal notch to the symphysis pubis. The incision extends from the suprasternal notch over the clavicle up to the acromioclavicular joint. Similarly done on the opposite side.

I-Shaped incision

Extending from the chin down to the symphysis pubis. The muscles of the chest are dissected away, keeping the edge of the knife directed inwards towards the ribs, carried back to the midaxillary line, down to the costal margin and up over the clavicles. The chest is opened by cutting the costal cartilages with a cartilage knife. Begin at the upper border of the second cartilage, keeping

very close to the costochondral junctions. The knife should be inclined about 30° to the vertical. In old persons where the rib cartilages are calcified, a pair of rib shears is used. Then, disarticulate the sternoclavicular joint on each side by holding the knife vertically and inserting the point into the semicircular joint. The position of this joint can be made out by moving the shoulder tip with the left hand, which causes the joint capsule to move. To divide the joint capsule, the knife is put in vertically and turned in a circular manner. Then the sternum is divided at its attachments with the diaphragm. The soft tissues are removed from the sternum as far as possible. By the above method all the sterna were removed. The advantage of taking in these methods is cosmetic. No separate incision or suture is seen on the body.

Technique of preparing specimens

Maceration of soft tissues was done by boiling the specimens in water to which 7 to 8 grams of sodium hydroxide was added per litre of water. Four litres of water were taken in an aluminium vessel to which the above mentioned quantity of sodium hydroxide was added. Four to five specimens of Sterna were immersed in this after proper labelling to prevent mixing up of specimens and then boiled for 60 to 75 minutes. Frequent examination was done to prevent over boiling and to find out the required extent of maceration.

The macerated specimens were then copiously washed with tap water. Portions of cartilage or soft tissues adhering to it were then removed with the help of a forceps and by gentle scrubbing with a soft brush. Specimens were then spread out on a clean piece of cloth for drying. 2 to 3 days will be required for

proper drying of specimens.

The technique was adopted after a discussion with my Guide and the authorities in the Regional Forensic Science Laboratory, Tirunelveli.

OSTEOMETRIC PARAMETERS USED FOR ANALYSIS

Measurements were taken using vernier calipers,

For sex determination, the following osteometric parameters were measured.[72]

1. Total length of sternum: Straight distance from the deepest point of the suprasternal notch to the point on the lower margin of the corpus Sterna in the mid-sagittal plane. When the sternum was not united as a single piece due to lack of fusion, individual segments were measured independently and the total length is calculated by adding all.
2. Length of body of sternum: Straight distance from the point on the lower margin of manubrium to the point on the lower margin of the body in the mid-sagittal plane.
3. Length of manubrium: Straight distance from the suprasternal notch to the point on the lower margin of the manubrium in the mid-sagittal plane.
4. Breadth of manubrium: Straight distance between the most laterally placed points on the lateral margins of the manubrium, taken at right angels to the length of the manubrium.
5. Breadth of body of sternum: The straight distance between the most laterally placed points on the lateral margins of the body taken at right angles to the length of the body.

6. Sternal index : $\frac{\text{Length of manubrium}}{\text{Length of body of sternum}} \times 100$

For age determination, fusion between the following regions was studied by naked eye examination. (Segments of the body of sternum are numbered from above downwards).

1. Between manubrium and the body
2. Between the various segments of the body
3. Between the xiphoid process and the body

For Stature Determination

The following osteometric parameters were used,

1. Total length of sternum
2. Length of manubrium
3. Length of body of sternum

There are two methods for determination of stature from skeletal remains ie, anatomical method and mathematical method. In anatomical method the stature is determined by simply putting the bones together in anatomical position and due allowance for the soft tissues and measuring the length. Though it provides more accurate estimate of stature it is applicable only when whole skeleton is available for examination. The mathematical method is based on the proportions of long bones to the height of an individual. This method is applicable even when a single bone is available. This method can be used in two ways, either by formulating prediction equation or by computing multiplication factor for

reconstruction of stature[66]. Hence mathematical method was the obvious choice for this study.

METHOD ADOPTED FOR ANALYSIS

Data collected was recorded, tabulated and statistically analysed under the guidance of a skilled statistician.

OBSERVATIONS AND RESULTS

Sternum from 100 medico-legal autopsies conducted on identified bodies during the period of June 2004 to June 2006 in the Department of Forensic Medicine, Tirunelveli Medical College, Tirunelveli, were collected and studied with a view to determine the sex, age and stature.

Sex

Out of 100 cases, 53 were males and 47 were females

Age

The lowest age in this sample was 14 years and the highest age was 75 years. The maximum number of cases (38, 38%) was in the 20 to 29 age group. The lowest age was 15 years for males and 14 years for females, while the highest age for males and females was 75 and 60 respectively.

Height of the Individuals:

The minimum height of the individuals (stature) in this study was 142cm and the maximum height (stature) was 179cm. The minimum height (stature) was 155cm for males and 142 cm for females, while maximum height (stature) was 176 cm and 167cm for males and females respectively.

MEASUREMENTS OF STERNUM

Of the 100 samples, only 91 samples were taken for the measurement of sternum, because the remaining 9 samples had non fusion of the body of the sternum and the length could not be calculated accurately by Vernier calipers.

1. Length of body of sternum in both sexes:

The minimum length of body of sternum was 54mm and maximum length was 108mm in both sexes. The mean length was 85.1 with a standard deviation of 13.1 and the median was 83mm in both sexes.

Maximum number of Specimens (15) was within the range of 80 - 85mm (16.48%).

II. Length of manubrium in both sexes:

In Both sexes the minimum length of manubrium was 38mm and the maximum length was 60mm. The mean was 47.8mm with a standard deviation of 5.2 and the median was 47mm in both sexes.

Maximum number of specimens (30) was within the range of 40 – 45mm (32.9%).

III. Breadth of body of sternum in both sexes:

The minimum breadth of body of sternum was 22mm and maximum breadth was 48mm. The mean was 34.1mm with a standard deviation of 5.7 and the median was 34 mm. Maximum number of specimens (33) fell within the range of 30 -35 mm (36.2%).

IV. Breadth of manubrium in both sexes:

The minimum breadth of manubrium was 40mm and the maximum breadth was 74mm. The mean was 56.6mm with a standard deviation of 7.3 and the median was 56 mm . Maximum number of specimens (27) were with in the

range of 50 -55mm (29.6%).

V. Total length of sternum in both sexes:

The minimum total length was 98 mm and the maximum was 160 mm. The mean was 131.4mm with a standard deviation of 15.8 and the median was 131mm. Maximum number of specimens (24) were within the range of 140-150mm (26.3%).

VI. Sternal index in both sexes:

The minimum value of this measurement was 37.3 and the maximum was 90.7. The mean was 56.3 with a standard deviation of 9.6 and the median was 55. Maximum number of specimens (21) were within the range of 55 – 60 (23%).

Table No. 1
Showing minimum, maximum, mean, median and Standard Deviation of the measurements for both males and females

	Mini mum	Maxi mum	Mean	Median	SD
Length of body of Sternum in mm	**54**	**108**	**85.1**	**83**	**13.1**
Length of Manubrium in mm	**38**	**60**	**47.8**	**47**	**5.2**
Breadth of Body of Sternum in mm	**22**	**48**	**34.1**	**34**	**5.7**
Breadth of Manubrium in mm	**40**	**74**	**56.6**	**56**	**7.3**
Total Length of sternum in mm	**98**	**160**	**131.4**	**131**	**15.8**
Sternal index	**37.3**	**90.7**	**56.3**	**56**	**9.6**
Height of individuals in cm	**142**	**179**	**161.4**	**160**	**9.1**

STERNAL MEASUREMENTS AND SEX OF THE INDIVIDUAL

1. Sex distribution of length of manubrium

The minimum length of manubrium was 38mm in males and 39mm in females while the maximum length of manubrium was 60mm and 50mm in males and females respectively.

The mean was 49.6mm with a standard deviation of 5.6 and the median was 50mm in Males. The mean was 45.8 mm with a standard deviation of 3.9 and the median was 45mm in females.

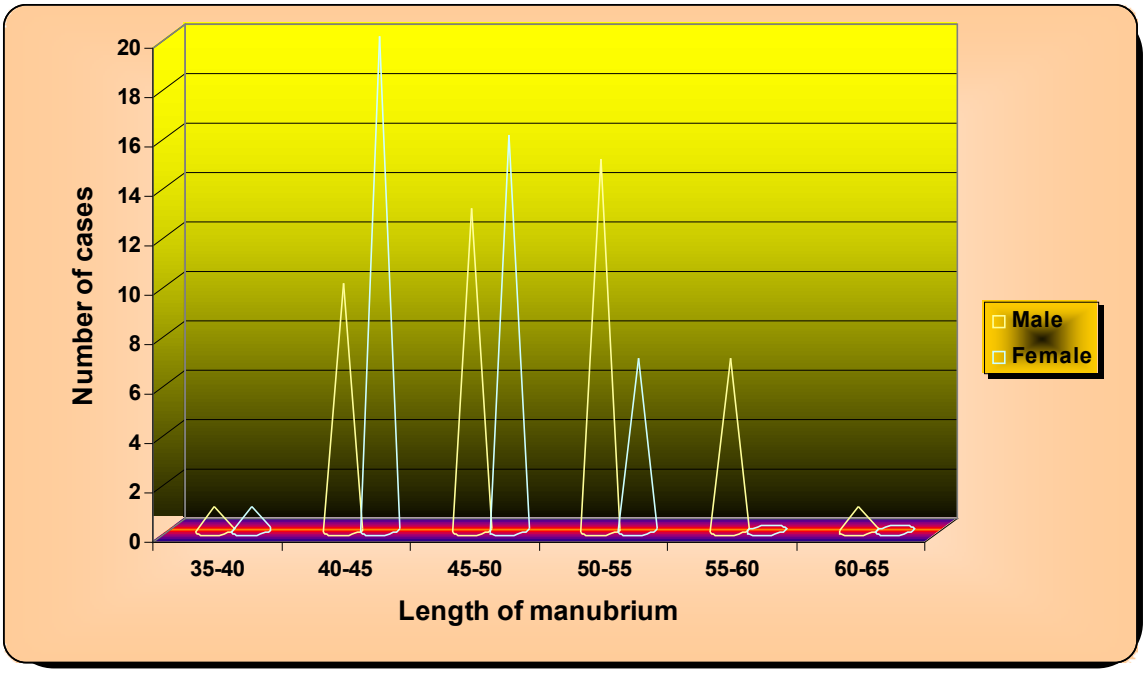
The difference noted in mean length is 3.8 mm which is highly significant from the statistical point of view. **If the length of the manubrium is more than 50 mm it could be a male as there was no female with a value above this.**

Table No. 2 Sex distribution of length of manubrium

Length of manubrium in mm	Male	Female	n
35-40	1	1	2
40-45	10	20	30
45-50	13	16	29
50-55	15	7	22
55-60	7	0	7
60-65	1	0	1
Total	47	44	91

Accuracy = males : 17%

Fig. 1: Sex distribution of length of manubrium



2. Sex distribution of length of body of sternum

The minimum length of body of sternum was 72 mm in males and 54 mm in females, while the maximum length of body of sternum in males and females was 108mm and 87mm respectively. The mean length was 94.1 mm with a standard deviation of 9.0 and the median was 95mm in males. The mean length was 75.5mm with a standard deviation of 9.3 and the median was 77mm in females.

The Difference in mean value is significantly greater (18.6) in males. In the total observations noted, there was no female with length of body of sternum greater than 87mm. Hence we can infer that **a person with the length of body of sternum greater than 87mm could be a male.**

Moreover there was no male with the length of body of sternum less than

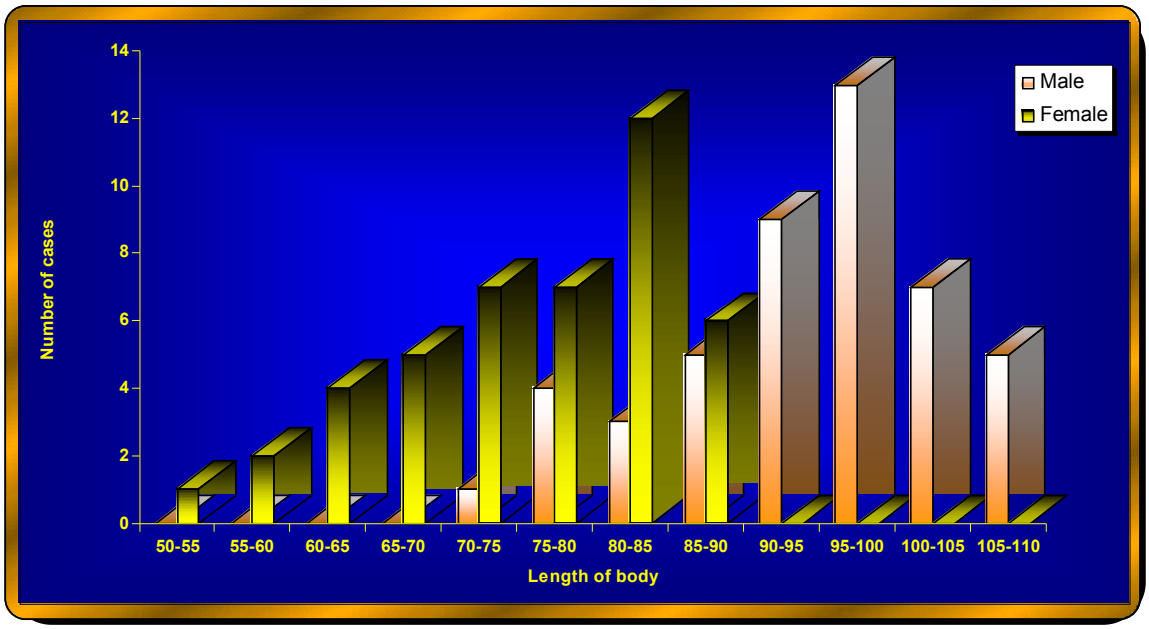
72mm. So we arrive the conclusion that **a person with the length of body of sternum less than 72mm could be a female.**

Table No.3 Sex distribution of length of body of sternum

Length of body of sternum in mm	Male	Female	n
50-55	0	1	1
55-60	0	2	2
60-65	0	4	4
65-70	0	5	5
70-75	1	7	8
75-80	4	7	11
80-85	3	12	15
85-90	5	6	11
90-95	9	0	9
95-100	13	0	13
100-105	7	0	7
105-110	5	0	5
Total	47	44	91

Accuracy = Males : 72% Females : 27%

Fig. 2: Sex distribution of length of body of sternum



3. Sex distribution of breadth of body of sternum

The minimum breadth of body of sternum was 29mm in males and

22mm in females, while the maximum breadth of body of sternum in males and females was 48mm and 38mm respectively. The mean breadth was 36.9mm with a standard deviation of 4.5 and the median was 36mm in males. Likewise in females, the mean breadth was 31.3mm with a standard deviation of 5.4 and the median was 32mm.

The difference of 5.6mm in mean is highly significant here as the variable has only a small measurement. It was noted that there was not even a single female with a measurement greater than 38mm. Hence we can assume that a sternum of an unknown could be **male if the breadth of the body of sternum is greater than 38mm.**

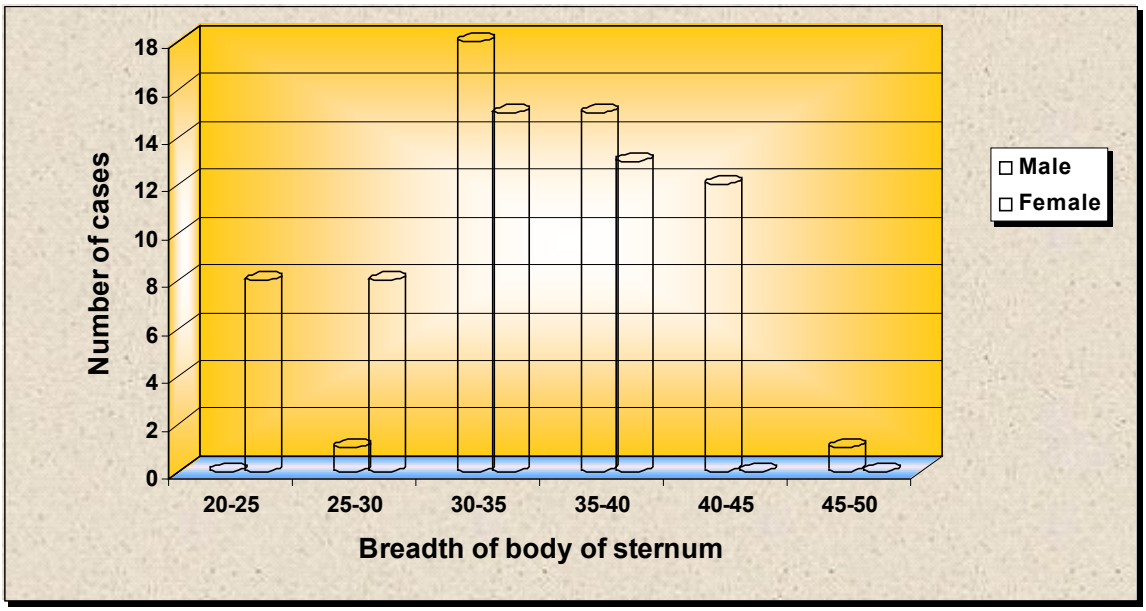
Moreover there was no male with the breadth of body of sternum less than 29mm. So we can infer that a sternum having **breadth of body of sternum less than 29mm could be a female.**

Table No. 4 Sex distribution of breadth of body of sternum

Breadth of Body in mm	Male	Female	n
20-25	0	8	8
25-30	1	8	9
30-35	18	15	33
35-40	15	13	28
40-45	12	0	12
45-50	1	0	1
Total	47	44	91

Accuracy = Males : 27% Females : 18%

Fig . 3: Sex distribution of breadth of body of sternum



4. Sex distribution of breadth of manubrium

The minimum breadth of manubrium was 48mm in males and 40mm in females, where the maximum breadth in males and females was 74mm and 60mm respectively. The mean breadth was 60.7mm with a standard deviation of 6.3 and the median was 61.0mm in males. But in females, the mean breadth was 52.2mm with a standard deviation of 5.5 and the median was 52.0mm .

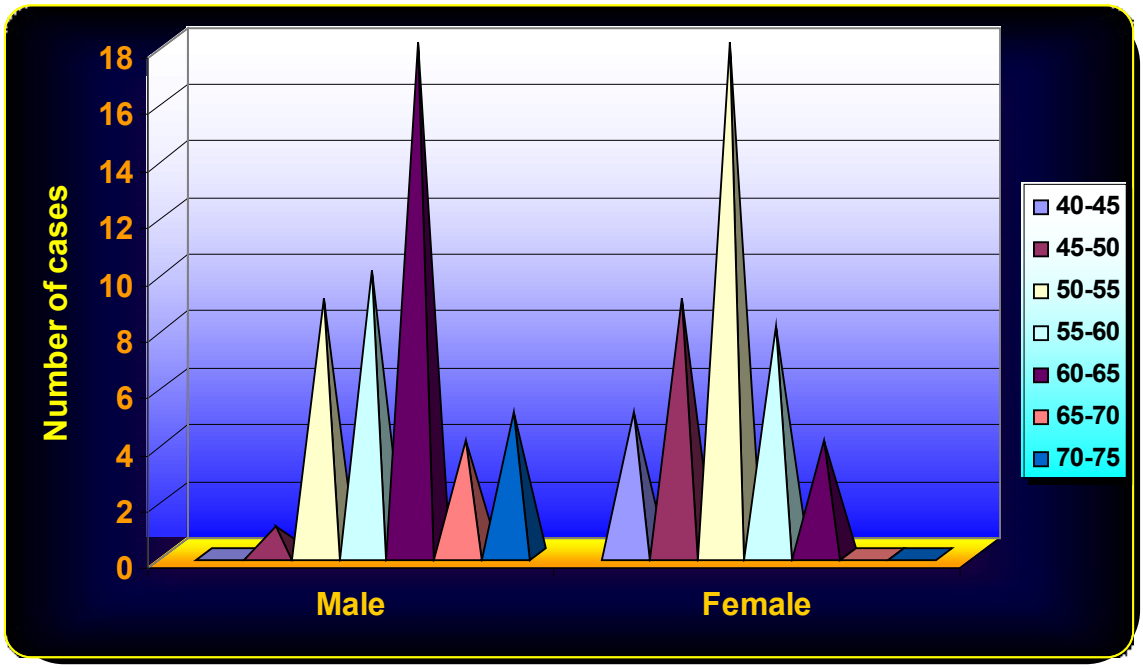
There was no female with a breadth greater than 60mm, so it can be concluded that a **sternum having manubrial breadth greater than 60mm could be a male**. Moreover no male with the breadth less than 48mm, Hence we decide that , **if the breadth of Manubrium is less than 48mm could belong to a female individual**.

Table No. 5 Sex distribution of breadth of manubrium

Breadth in mm	Male	Female	n
40-45	0	5	5
45-50	1	9	10
50-55	9	18	27
55-60	10	8	18
60-65	18	4	22
65-70	4	0	4
70-75	5	0	5
Total	47	44	91

Accuracy = Males : 20% Females : 11%

Fig. 4: Sex distribution of breadth of manubrium



5.Sex distribution of sternal index

The minimum sternal index was 37.3 in Males and 47.1 in females, while the maximum was 69.4 and 90.7 in Males and females respectively. The mean sternal index was 52.3 with a standard deviation of 8.4 and the median was 51 in Males. But that was 60.6 with a standard deviation of 9.0 and the median was 59.0 in females.

Mean sternal index was significantly higher in females. All the males

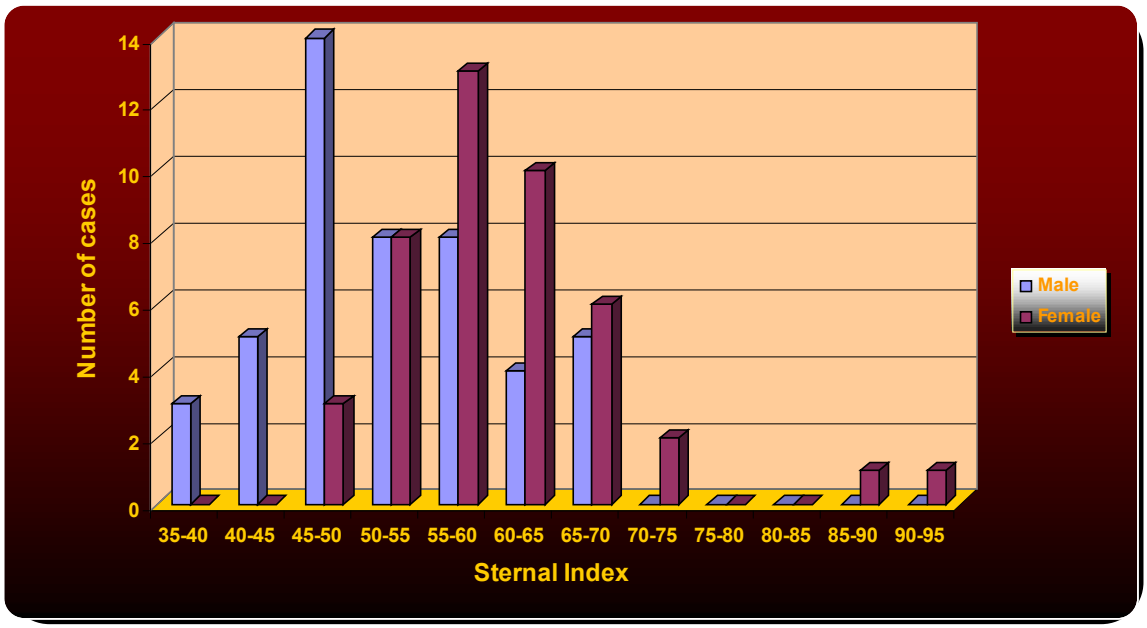
showed a sternal index of 69.4 or below. At the same time, All the females showed the sternal index of 47.1 or above. So we can very well conclude that a sternum with **the sternal index of 70 or above could be a female and 47 or below could be a male**.

Table No. 6. Sex distribution of Sternal index

Sternal index	Male	Female	n
35-40	3	0	3
40-45	5	0	5
45-50	14	3	17
50-55	8	8	16
55-60	8	13	21
60-65	4	10	14
65-70	5	6	11
70-75	0	2	2
75-80	0	0	0
80-85	0	0	0
85-90	0	1	1
90-95	0	1	1
Total	47	44	91

Accuracy = Males : 17% Females : 9%

Fig. 5: Sex distribution of Sternal index



6. Sex distribution of total length of Sternum

The minimum total length was 119mm in males and 98mm in females whereas maximum was 160mm and 136mm in males and females respectively. The mean total length was 142.7mm with a standard deviation of 10.1 and the median was 142mm in males. But in females, mean total length was 119.3mm with a standard deviation of 11.3 and the median was 114mm.

Mean total length is significantly higher in males. There were no females with a total length of greater than 136mm. Hence **we can assume a person as male if the value measured is more than 136mm**. Moreover, No males were there with a total length of less than 119mm. So once again we can infer that a **sternum with the total length below 119mm could belong to a female individual.**

Table No. 7 Sex distribution of total length of sternum

Total length in mm	Male	Female	n
90-100	0	1	1
100-110	0	9	9
110-120	1	14	15
120-130	5	10	15
130-140	8	10	18
140-150	24	0	24
150-160	8	0	8
160-170	1	0	1
Total	47	44	91

Accuracy = Males : 70% Females : 22%

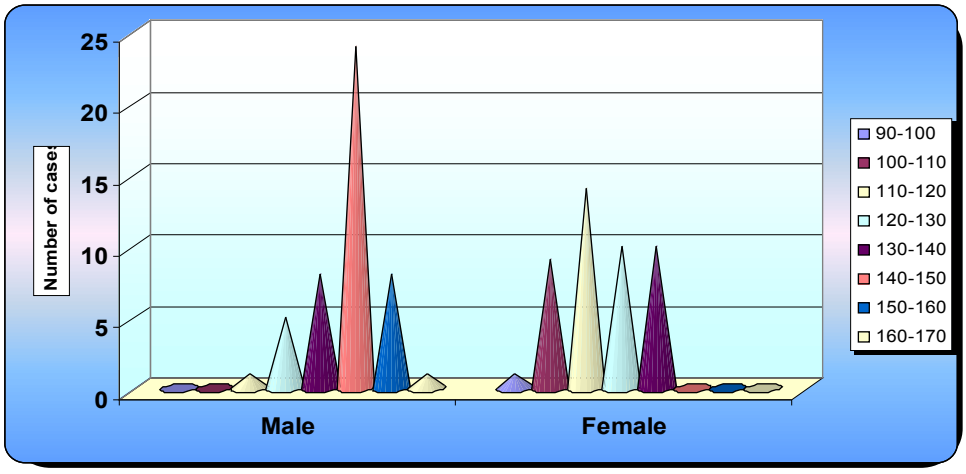


Fig .6.

Sex distribution of total length of sternum

Table No.8 Showing minimum, maximum, mean, median and Standard Deviation of the measurements in males

	Mini mum	Maxi mum	Mean	Median	SD
Length of Body of Sternum in mm	72	108	94.1	95	9.0
Length of Manubrium in mm	38	60	49.6	50	5.6
Breadth of Body of Sternum in mm	29	48	36.9	36	4.5
Breadth of Manubrium in mm	48	74	60.7	61	6.3
Total Length of sternum in mm	119	160	142.7	142	10.1
Sternal index	37.3	69.4	52.3	51	8.4
Height of individuals in cm	155	179	161.5	166	6.8

Table No. 9 Showing minimum, maximum, mean, median and Standard Deviation of the measurements in females

	Mini mum	Maxi mum	Mean	Median	SD
Length of Body of Sternum in mm	54	87	75.5	77	9.3
Length of Manubrium in mm	39	50	45.8	45	3.9
Breadth of Body of Sternum in mm	22	38	31.3	32	5.4
Breadth of Manubrium in mm	40	60	52.2	52	5.5
Total Length of sternum in mm	98	136	119.3	114	11.3
Sternal index	47.1	90.7	60.6	59	9.0

Height of individuals in cm	**142**	**167**	**154.9**	**155**	**6.4**

Table .10 Mean value and p value of the measurements

Variable	Mean value		p Value
	Male	Female	
Length of Body of Sternum in mm	94.1	75.5	p<0.0001
Length of Manubrium in mm	49.6	45.8	p<0.001
Breadth of Body of Sternum in mm	36.9	31.3	p<0.0001
Breadth of Manubrium in mm	60.7	52.2	p<0.0001
Total Length of sternum in mm	142.7	119.3	p<0.0001
Sternal index	52.3	60.6	p<0.001

Table No. 11 SEX & STERNAL PARAMETERS

	MALE	FEMALE
Length of Body of Sternum in mm	72-108	54-87
Length of Manubrium in mm	38-60	39-50
Breadth of Body of Sternum in mm	29-48	22-38
Breadth of Manubrium in mm	48-74	40-60
Total Length of sternum in mm	119-160	98-136
Sternal index	37.3-69.4	47.1-90.7

AGE DETERMINATION FROM FUSION OF STERNAL COMPONENTS

Fusion between segments of the body of sternum

(Segments of the body of sternum are numbered from above downwards)

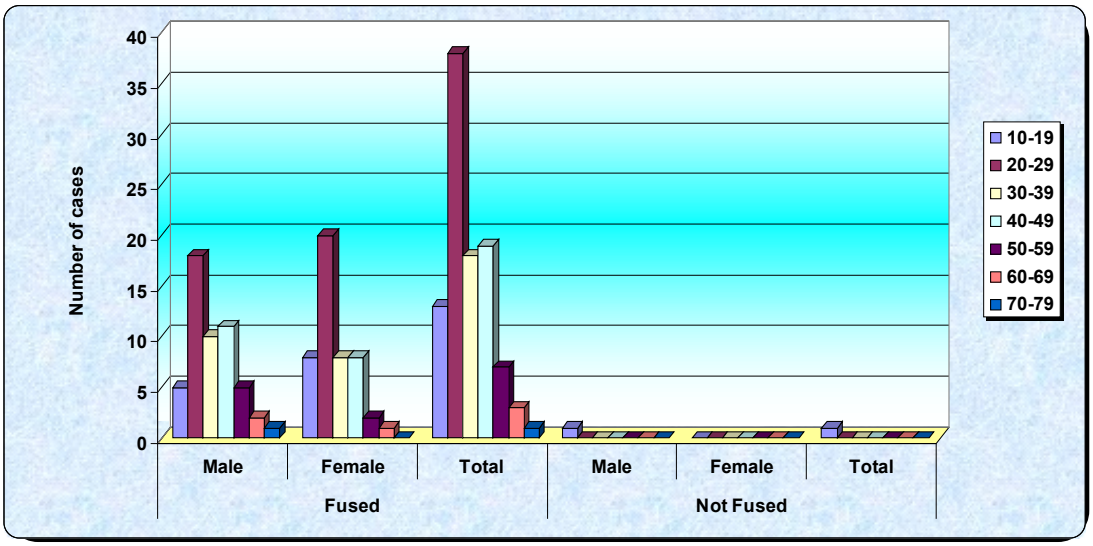
I. Fusion between 3rd and 4th segments

Lowest age in this sample was 14 years. Fusion between 3rd and 4th segments might have started even below the age of 14 years. Fusion was 92.8% in the 10-19 years of age group. Up to the age of 16 years, the fusion was 80%. Above that fusion was 100% irrespective of sex.

Table 12
Fusion between 3rd and 4th segments of body (N=100)

Age	Fused			Not Fused			N	% showing fusion
	Male	Female	Total	Male	Female	Total		
10-19	5	8	13	1	0	1	14	92.85
20-29	18	20	38	0	0	0	38	100
30-39	10	8	18	0	0	0	18	100
40-49	11	8	19	0	0	0	19	100
50-59	5	2	7	0	0	0	7	100
60-69	2	1	3	0	0	0	3	100
70-79	1	0	1	0	0	0	1	100
Total	52	47	99	1	0	1	100	99

Fig.7. Fusion between 3rd and 4th segments of body (N=100)



II. Fusion between 2nd and 3rd segments

Fusion of these segments was not observed below 15 years. In this

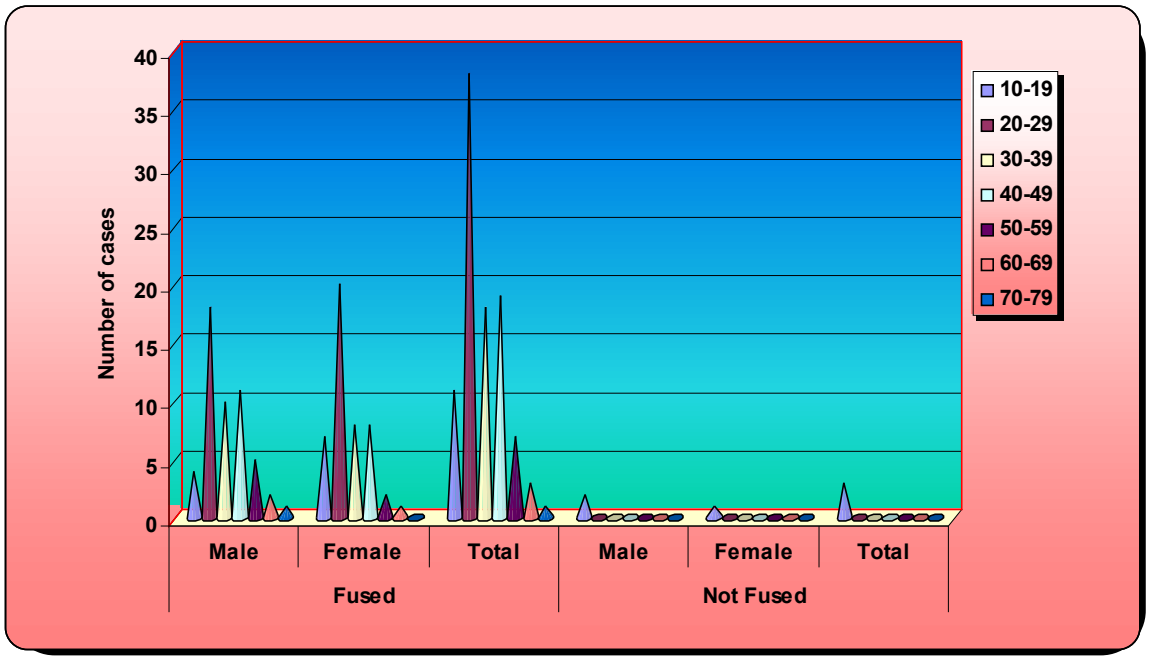
sample, fusion has started, only above 14 years. Between the ages of 14-16years, 40% showed fusion. Above that, the fusion was 100%.

Table 13

Fusion between 2nd and 3rd segments of body (N=100)

Age	Fused			Not Fused			N	% showing fusion
	Male	Female	Total	Male	Female	Total		
10-19	4	7	11	2	1	3	14	78.57
20-29	18	20	38	0	0	0	38	100
30-39	10	8	18	0	0	0	18	100
40-49	11	8	19	0	0	0	19	100
50-59	5	2	7	0	0	0	7	100
60-69	2	1	3	0	0	0	3	100
70-79	1	0	1	0	0	0	1	100
Total	51	46	97	2	1	3	100	97

Fig.8 Fusion between 2nd and 3rd segments of body (N=100)



III. Fusion between 1st and 2nd segments

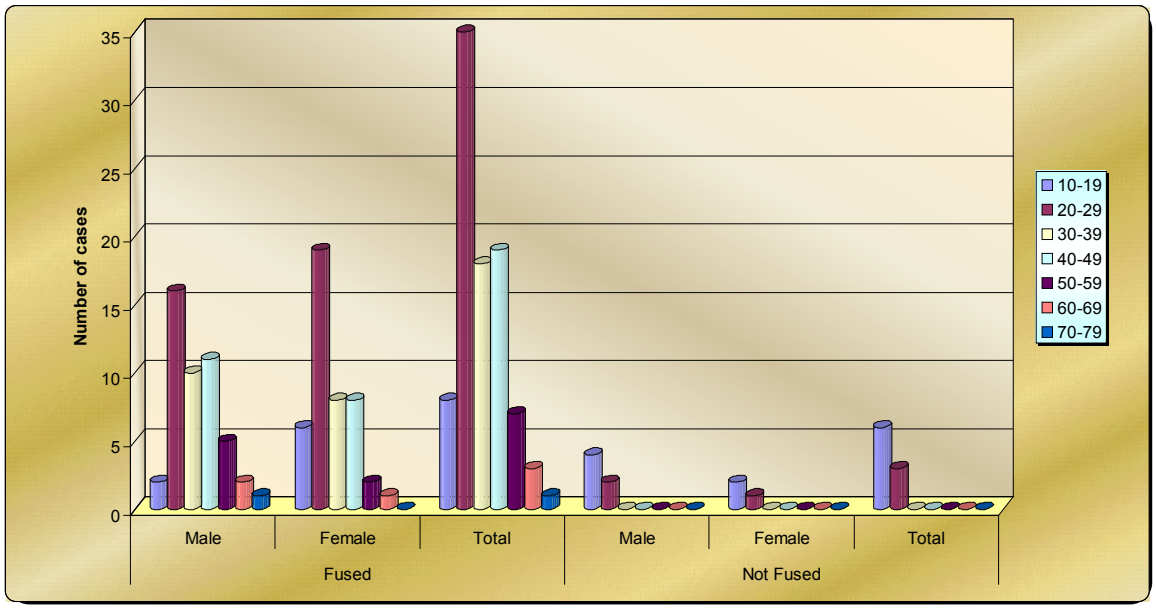
Fusion between these two segments was not observed below 16 years. In

10-19 years of age group, only 57.14% showed fusion. The fusion was 100% above the age of 21 years.

Table 14
Fusion between 1st and 2nd segments of body (N=100)

Age	Fused			Not Fused			N	% showing fusion
	Male	Female	Total	Male	Female	Total		
10-19	2	6	8	4	2	6	14	57.14
20-29	16	19	35	2	1	3	38	92.10
30-39	10	8	18	0	0	0	18	100
40-49	11	8	19	0	0	0	19	100
50-59	5	2	7	0	0	0	7	100
60-69	2	1	3	0	0	0	3	100
70-79	1	0	1	0	0	0	1	100
Total	47	44	91	6	3	9	100	91

Fig. 9 Fusion between 1st and 2nd segments of body (N=100)



IV. Fusion between xiphoid process and body of sternum

Fusion of these two segments were not observed below 32 years and 11%

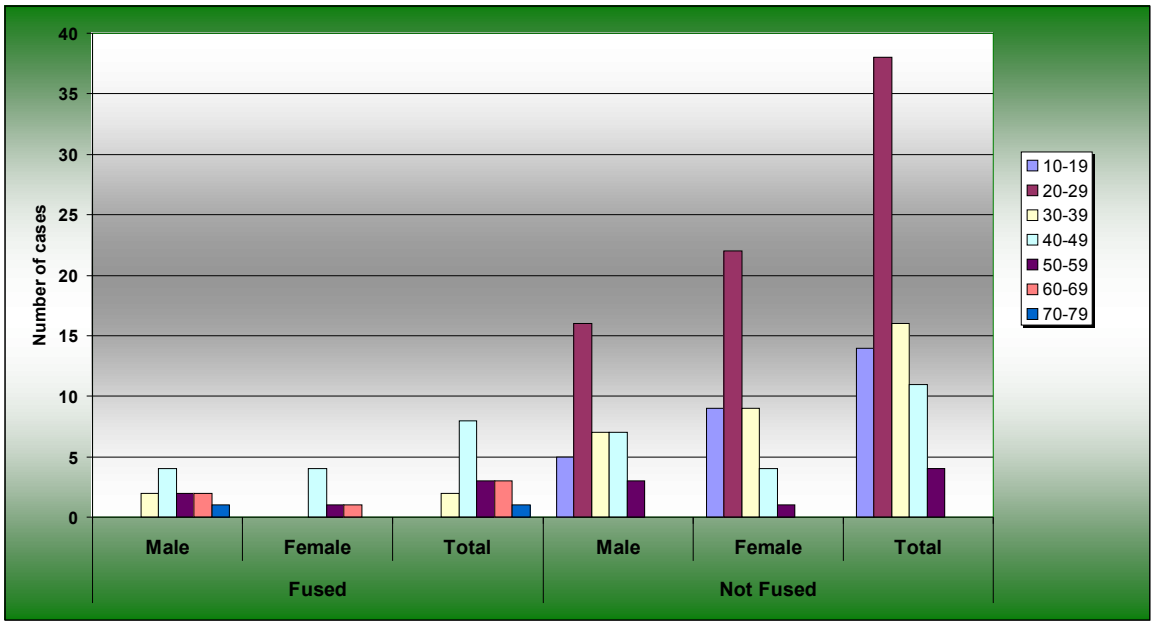
showed fusion in the 30 – 39 years of age group. 22% of the **Males showed fusion between 30-39 years of age group**. No females showed fusion in the age group of 30 – 39 years. **Fusion started in females from 40years** of age group. 50% of fusion was observed among females between the age group of 40 -49 years.

Above the age of 40 years the percentage of cases showing fusion were found to be steadily increasing with advancing age (given in table). **The fusion was 100% from 60 years onwards irrespective of the sex.**

Table . 15
Fusion between xiphoid process and body of sternum (N=100)

Age	Fused			Not Fused			N	% showing fusion
	Male	Female	Total	Male	Female	Total		
10-19	0	0	0	5	9	14	14	0
20-29	0	0	0	16	22	38	38	0
30-39	2	0	2	7	9	16	18	11.11
40-49	4	4	8	7	4	11	19	42.10
50-59	2	1	3	3	1	4	7	42.80
60-69	2	1	3	0	0	0	3	100
70-79	1	0	1	0	0	0	1	100
Total	11	6	17	38	45	83	100	17

Fig. 10. Fusion between xiphoid process and body of sternum (N=100)



V. Fusion between manubrium and body of sternum

Fusion of these segments was not observed below 35 years in males and 43 years in females. 33.3 % of cases in the age group of 60 -69 years showed fusion and 28.57% in the age group of 50 -59 years.

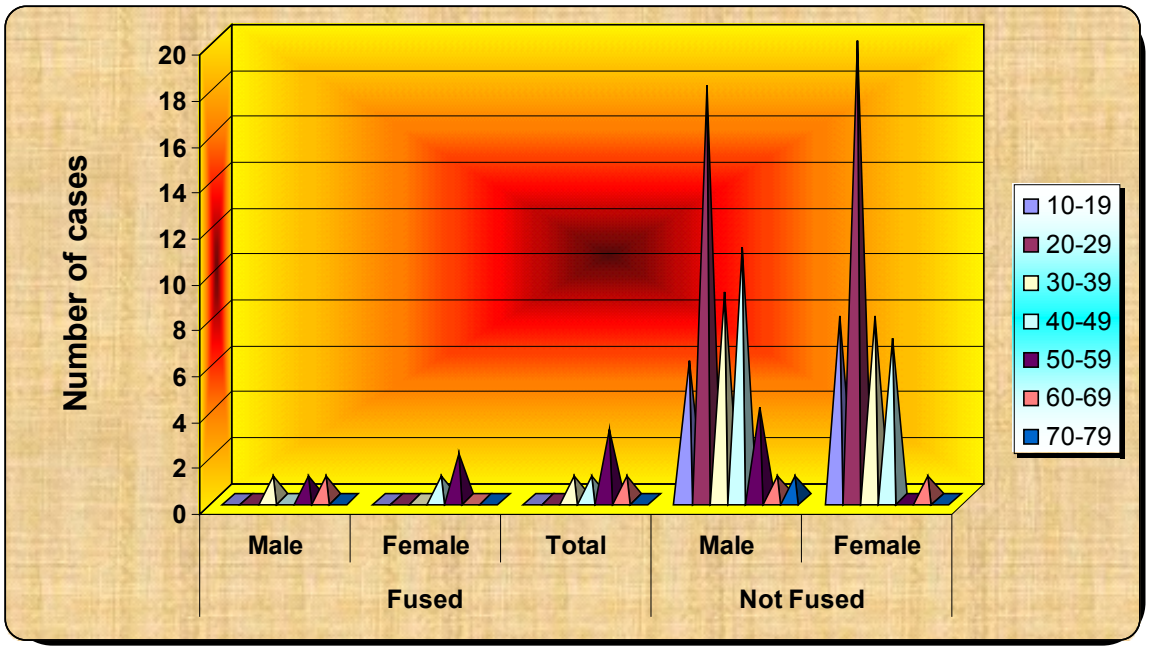
Non fusion of these segments was observed even at 75 years in a male and 60 years in a female.

Table . 16

Fusion between manubrium and body (N=100)

Age	Fused			Not Fused			N	% showing fusion
	Male	Female	Total	Male	Female	Total		
10-19	0	0	0	6	8	14	14	0
20-29	0	0	0	18	20	38	38	0
30-39	1	0	1	9	8	17	18	5.5
40-49	0	1	1	11	7	18	19	5.5
50-59	1	2	3	4	0	4	7	28.57
60-69	1	0	1	1	1	2	3	33.3
70-79	0	0	0	1	0	1	1	0
Total	3	3	6	50	44	94	100	6

Fig.11. Fusion between manubrium and body



Fusion between 1st and 2nd segments has started above the age of 16 years. The fusion reaches 100% by the age of 21 years.

Fusion between 2nd and 3rd segments has started above the age of 14 years. 100% fusion was achieved only above the age of 16years.

Fusion between 1st and 2nd segments might have started even before 14 years which is the minimum age in the sample. These segments showed 100 % fusion above the age of 16 years which is irrespective of the sex, as similar to the fusion between and 2nd and 3rd segments.

As per this study, fusion between the segments of sternal body seems to be more reliable one. It may be safely assumed that in almost all the cases , all **the segments of the body of sternum tend to show fusion within the age of 21 years .**

Fusion between manubrium and body of sternum were observed above

35 years in males and above 43 years in females. Non fusion of these segments was noted even at the age of 75 years in males and 60 years in females which are the highest age in this sample for males and females respectively. In case of union between manubrium and body, the pattern of incidence of fusion with increasing age is almost similar to that between xiphoid and body.

By this study, if the **manubrium and body of sternum is not fused, we can assume that the age of the Individual is less that 35 years (in males) and less than 43 years (in females)**. However, before arriving this conclusion the sex of the individual to whom the specimen belongs should have been determined.

Fusion between Xiphoid and body of sternum starts from the age of 32 years in males whereas, in females from the age of 40 years. 100% of fusion occurs above the age of 60 years in both sexes.

If the xiphoid process and body of sternum is fused and the sex also had been determined , we can very well conclude that, the age of the individual is more than 32 years (in males) and more than 40 years (in females).

Age determination from union of manubrium and xiphoid with the body, does not seem to be reliable.

Determination of stature in a Male individual from Sternal measurements:

The lowest stature for males in this sample was 155cm and the highest stature was 179cm. The mean was 161.5 with a standard deviation of 6.8cm and the median was 166cm. The regression formulae used were as follows:

1. y = 137.1 + 3.1x (For length of body)
2. y = 160.9 + 1.04x (For length of Manubrium)
3. y = 122+3.1x (For total length)

In the above formulae the 'y' means calculated stature. 'x' are measurements of sternum.

The table showing the correlation between the stature and the sternal measurements in males is shown in Annexure 6.

A standard error of estimate obtained in this study with the length of body was ± 3.2. By applying the above error, we can determine the stature of an individual with 68% confidence. If we multiply the standard error of estimate by 2, Stature can be estimated with 95% confidence . Determination of stature with 98% confidence can be acquired by multiplying the standard error of estimate by 3. The coefficient of correlation(r) was 0.42.

A standard error of estimate obtained in this study with the length of manubrium was ± 4.4. By applying the above error, we can determine the stature of an individual with 68% confidence. If we multiply the standard error of estimate by 2, Stature can be estimated with 95% confidence. Determination of stature

with 98% confidence can be attained by multiplying the standard error of estimate by 3. The coefficient of correlation(r) was 0.15.

A standard error of estimate got in this study with the total length was ± 3.3. By applying the above error, we can determine the stature of an individual with 68% confidence. If we multiply the standard error of estimate by 2, Stature can be estimated with 95% confidence. Determination of stature with 98% confidence can be obtained by multiplying the standard error of estimate by 3. The coefficient of correlation(r) was 0.44.

Table . 17

Characters	Male		
	Regression formula	**Standard error of estimate**	**Co-efficient of correlation**
Length of body of sternum	y = 137.1 + 3.1x	±3.2	0.42
Length of manubrium	y = 160.9 +1.04x	±4.4	0.15
Total length	y = 122 + 3.1x	±3.3	0.44

Determination of stature from length of body of sternum or total length of sternum seems to be more reliable than from length of manubrium as the range of standard error of estimate is narrow.

Determination of stature in a Female individual from Sternal measurements:

The lowest stature for males in this sample was 142 cm and highest stature was 167cm . The mean was 154cm with a standard deviation of 6.4cm and the median was 155cm. The regression formulae used were as follows:

1. y = 126.76 + 3.6x (For length of body)
2. y = 130.6 + 5.2 x (For length of Manubrium)
3. y = 110 +3.7x (For total length)

In the above formulae the 'y' means calculated stature. 'X' are measurements of sternum.

The table showing the correlation between the stature and the sternal measurements in females is shown in Annexure 8.

A standard error of estimate obtained in this study with the length of body was ± 4.0. By applying the above error, we can determine the stature of an individual with 68% confidence. If we multiply the standard error of estimate by 2, Stature can be estimated with 95% confidence. Determination of stature with 98% confidence can be acquired by multiplying the standard error of estimate by 3. The coefficient of correlation(r) was 0.49.

A standard error of estimate obtained in this study with the length of manubrium was ± 5.3. By applying the above error, we can determine the stature of an individual with 68% confidence. If we multiply the standard error of

estimate by 2, Stature can be estimated with 95% confidence. Determination of stature with 98% confidence can be attained by multiplying the standard error of estimate by 3. The coefficient of correlation(r) was 0.3.

A standard error of estimate got in this study with the Total length was ± 4.5. By applying the above error, we can determine the stature of an individual with 68% confidence. If we multiply the standard error of estimate by 2, Stature can be estimated with 95% confidence. Determination of stature with 98% confidence can be obtained by multiplying the standard error of estimate by 3. The coefficient of correlation(r) was 0.56.

Table . 18

Characters	Female		
	Regression formula	**Standard error of estimate**	**Co-efficient of correlation**
Length of body of sternum	y = 126.76 + 3.6x	±4.0	0.49
Length of manubrium	y = 130.6 + 5.2 x	±5.3	0.3
Total length	y = 110 +3.7x	±4.5	0.56

Determination of stature from length of body is more reliable than from the length of manubrium or total length as the range of standard error of estimate is narrow.

Determination of stature in both sexes as a whole from sternal measurements:

The lowest stature for males in this sample was 142 cm and highest stature was 179cm. The mean was 161cm with a standard deviation of 9.1cm and the median was 160cm. The regression formulae used were as follows:

4. y = 117.3 + 5.1 x (For length of body)
5. y = 116.6 + 9.1 x (For length of Manubrium)
6. y = 93.6 + 5.1x (For total length)

In the above formulae the 'y' means calculated stature. 'X' are measurements of sternum.

The table showing the correlation between the stature and the sternal measurements in both sexes is shown in Annexure 9 .

A standard error of estimate obtained in this study with the length of body was ± 4.4. By applying the above error, we can determine the stature of an individual with 68% confidence. If we multiply the standard error of estimate by 2, Stature can be estimated with 95% confidence . Determination of stature with 98% confidence can be acquired by multiplying the standard error of estimate by 3. The coefficient of correlation(r) was 0.73.

A standard error of estimate obtained in this study with the length of manubrium was ± 7.3. By applying the above error, we can determine the stature of an individual with 68% confidence. If we multiply the standard error of estimate by 2, Stature can be estimated with 95% confidence. Determination of

stature with 98% confidence can be attained by multiplying the standard error of estimate by 3. The coefficient of correlation(r) was 0.38.

A standard error of estimate got in this study with the total length was ± 4.8. By applying the above error, we can determine the stature of an individual with 68% confidence. If we multiply the standard error of estimate by 2, Stature can be estimated with 95% confidence. Determination of stature with 98% confidence can be obtained by multiplying the standard error of estimate by 3. The coefficient of correlation(r) was 0.78.

Table. 19

Characters	Female		
	Regression formula	**Standard error of estimate**	**Co-efficient of correlation**
Length of body of sternum	y = 117.3 + 5.1 x	±4.4	0.73
Length of manubrium	y = 116.6 + 9.1 x	±7.3	0.38
Total length	y = 93.6 + 5.1x	±4.8	0.78

Determination of stature from length of body or total length are more reliable than from length of manubrium as the range of standard error of estimate is narrow.

DISCUSSION

Sternae from 100 documented medicolegal autopsies conducted during the period between June 2004 and June 2006 were retrospectively studied and the observations were analysed statistically to determine age, sex and stature. The design adopted is cross sectional as the aim of the study is to determine sex, age and stature of an individual. Of the 100 specimens, 91 specimens were used for the determination of sex and stature only since the body of the remaining 9 specimens were impossible to measure by vernier caliper due to Non-fusion of their individual segments.

SEX DETERMINATION

It is quite obvious from the foregoing observations that all parameters measured have a higher value in males except sternal index which is greater in females. This is in total agreement with previously studies. [11,39,40,48,49,51,57.]

All the parameters of the sternum (i.e) the length , breadth of the body, breadth of the manubrium, sternal index and total length showed significant statistical difference between males and females. When the length of manubrium was taken into consideration, it was found to be of not much significance, since a specific cut – off value could not be found out for females, (Due to the values below 50mm were equivocal). This is in good agreement with the observations of previous workers, [49] who were of the opinion that length of manubrium is not a useful index in sexing a given sternum.

The sternal index is found characteristically high in all the studies in

females. [11,40,43,44] This is reflected in the higher values obtained for females (70 or above) in this study also when when compared to that of males males (47 or below). Sternal index is calculated from the formula:

$$\frac{\text{Length of manubrium X 100}}{\text{Length of body}}$$

The reason for the higher value of sternal index in females may be attributed to the following:

The length of manubrium exceeds half the length of body of the sternum in females; while in males, the length of body of sternum is at least twice the length of manubrium. This view which had been put forward by many authors and workers[40,42,43] has also been noticed in the present study. This observation could also explain the reason for the statistical non significant difference in the measurements of length of manubrium in males and females. One author is of the view that the manubrium is somewhat smaller in males while bigger in females. [47] Jit.I, Jhingan and Kulkarni have opined that manubrium corpus index is not useful in sexing a given sternum.

The mean length of body of the sternum was found to be significantly higher in males (94.1mm) than females (75.5mm). This observation is in close agreement with those of Wenzel, Krogman, Paterson, Jit.I, Jhingan and kulkarni and M.N.Vijayan have all suggested that length of body of the sternum is greater in males.

The mean total length of sternum is also significantly higher in males (142.7mm) than in females (119.3mm). This finding again is in concordance with the observations of Jit.I and Kaur.H, Jhingan, Kulkarni and M.N. Vijayan. But no critical value as suggested by Ashley ("149 rule, 136 rule") could be worked out in this study.

All studies conducted by other researchers, provide two cut off values for sex determination i.e a value above which the sternum could be sexed as male and below which it could be female. But researchers like jit.I, Kulkarni and Jhingan had frankly admitted that the measurements in between these cut off values cannot be properly categorized as to whether belonging to a male or female. If the value obtained for a given sternum lies in between these cut off limits, then no opinion regarding sex can be derived. The inability to determine the sex for those sterna having measurements within these limits seems to be obvious in all previous studies. [39,40,48,49,53,67]

In a similar manner, the present study shows that a significant number of sternae fall within the equivocal range only. So in order to avoid such ambiguities, the present study mentions only of a definite cut off value above or below which the sternum can actually be sexed. This study also provides the mean value for each and every measurement (sex – wise) which would help to give an idea regarding the sex of the individual.

Therefore in conclusion it can be said that a subject could be **male** if the**:**

1. Length of body of sternum is greater than 87mm.
2. Length of manubrium is greater than 50mm.
3. Breadth of body of sternum is greater than 38 mm.
4. Breadth of manubrium is greater than 60mm.
5. Sternal index is 47 or below.
6. Total length of sternum is more than 136mm.

A subject could be **female** if the**:**

1. Length of body of sternum is less than 72 mm.
2. Breadth of manubrium is less than 48 mm.
3. Breadth of body of sternum is below 29 mm.
4. Sternal index is 70 or above.
5. Total length is below 119 mm.

But this conclusion was observed leaving out the group which was equivocal. The following chart is explicit as to the percentage of accuracy in determination of sex.

Accuracy of the above results are shown below

	Male	**Female**
Length of body of sternum	72%	27%
Length of manubrium	17%	-
Breadth of body of sternum	27%	18%
Breadth of manubrium	20%	11%
Total Length of sternum	70%	22%
Sternal index	17%	9%

(Accuracy is derived with the base value of 100% both male and female)

Accuracy is more with length of body of the sternum and Total length of sternum in both sexes. When we take as a whole, length of body of the sternum and total length of the sternum in males are more reliable parameters

AGE DETERMINATION

Age estimation from skeletal remains is a challenging assignment vested in a Forensic pathologist. Since biological and geographical variations influence skeletal growth, the actual age determination is a difficult task. So for a specific geographical area, the data obtained from that particular region would help to develop a standard for age estimation.

Fusion of Sternebrae

According to the present study, fusion between 2nd, 3rd and 4th segments of body of the sternum was observed above the age of 16 years. Fusion between 1st and 2nd segments was noticed above the age of 21 years.

Almost all cases above 21 years of age showed fusion between all segments of the body of the sternum.

No difference could be observed between males and females in the age of fusion of sternebrae.

This observation seems to confirm the following previous studies with negligible variations:

1. Union of body elements of sternum was completed by around 20 years (Dwight).

2. Fusion of component segments of body of sternum was found to be completed by 22 to 23 years. (Mckern and Stewart).
3. The 4 segments of body of sternum fuse with each other from below in childhood, at puberty and at 21 years. (Ashley).
4. Body pieces unite to form a single bone by the age of 25 years. (W.J.Hamilton).
5. According to most authors the four middle pieces constituting the body of sternum fuse with one another from below upwards between 14 and 25 years. [31,36,37,38,76,77].
6. A mesosternum showing fusion of all segments must be from a subject over 16 years if male and over 18 years if female. (Jit.I and Kaur. H).

Fusion of Xiphoid Process With Body of the Sternum:

Fusion between xiphoid process with body of the sternum was not observed below 32 years in males and below 40 years in females. 11% of cases showed fusion between 30 – 39 years. Above 39 years it was steadily increasing, and reached 42.8% by the age of 50 – 59 years. But above 60 years fusion reached 100%. Hence fusion of xiphoid with body occurs anywhere in between 32 – 60 years irrespective of sex.

This observation is in good agreement with the following Previous studies:

1. The Xiphisternum unites with the body by about 40 – 50 years (Girdany & Golden).
2. Union of body with the Xiphoid is extremely variable (Dwight.T).

3. The Xiphoid does not join the body until middle age (Krogman).
4. The xiphoid unites with the body of sternum at above 40th year. [36,37,38,76,77].
5. Fusion of xiphoid with the body occurred in between 22 to 44 years (M.N.Vijayan).
6. Union of Xiphoid with the body of sternum is rather unpredictable (Renju Ravindran).
7. Fusion starts after 30 years and completes after the age 0f 50 (Gautham and R.S.Shah)

Fusion of Manubrium With Body of the Sternum:

The fusion of manubrium with body of sternum was not observed below 35 years in males and below 43 years in females. There were 28.5% of cases showing fusion in the 50 – 59 years of age group. 33.3% of cases showed fusion in the 60 -69 years of age group.

This observation again seems to confirm to the views of :

1. M.N.Vijayan who suggested that incidence of fusion with body is very low.
2. Dwight who stated that union of body with manubrium was extremely variable.
3. Keith Simpson has also stated that disappearance of manubriosternal joint may occur in a period from 50 years to death but this has been observed to be cartilaginous even in

a centenarian.

4. Most other authors suggest that the manubrium either unites in old age or that sometimes it never fuses even in advanced old age. [36,37,38,76,77.]

STATURE DETERMINATION

Determination of stature from long bones has been carried out by various researchers and they have succeeded in that by finding various mathematical solutions. But as far as other flat bones are concerned, it is still incomplete.

Regression formulae and the standard error of estimates obtained in this study on males and females are shown below:

Characters	Male		
	Regression formula	**Standard error of estimate**	**Co-efficient of correlation**
Length of body of sternum	y = 137.1 + 3.1x	±3.2	0.42
Length of manubrium	y = 160.9 +1.04x	±4.4	0.15
Total length	y = 122 + 3.1x	±3.3	0.44

Determination of stature in males from length of body or total length seems to be more reliable than from length of manubrium.

Characters	Female		
	Regression formula	**Standard error of estimate**	**Co-efficient of correlation**
Length of body of sternum	y = 126.76 + 3.6x	±4.0	0.49
Length of manubrium	y = 130.6 + 5.2 x	±5.3	0.3
Total length	y = 110 +3.7x	±4.5	0.56

Determination of stature in females from length of body is more reliable than from the length of manubrium or total length.

Characters	Both sexes		
	Regression formula	**Standard error of estimate**	**Co-efficient of correlation**
Length of body of sternum	y = 117.3 + 5.1 x	±4.4	0.73
Length of manubrium	y = 116.6 + 9.1 x	±7.3	0.38
Total length	y = 93.6 + 5.1x	±4.8	0.78

Determination of stature in both sexes from length of body and total length are more reliable than from length of manubrium.

On analysis of all the observations, it is explicit that the length of body of sternum is the more reliable parameter in determination of stature of an individual. However the confidence limit by using the standard error that is derived from this study is only 68%. So these regression formulae can be used for determination of stature where there are no other suitable alternative methods .This observation is agreed by many authors like Dwight.T[53], Trotter.M and TH. Bijoy Singh. [66.]

SUMMARY AND CONCLUSIONS

The Sternae collected from 100 documented cases of medicolegal autopsies during the period from June 2004 to June 2006 were studied with a view to determine sex, age and stature of a person.

Analysis of data showed the following conclusions

- We could categorize an unknown skeleton as **male** if the :
    1. Length of manubrium is more than 50 mm.
    2. Length of body of sternum is greater than 87 mm.
    3. Breadth of manubrium is more than 60 mm.
    4. Breadth of body of sternum is more than 38 mm.
    5. Sternal index is 47 or below.
    6. Total length is more than 136 mm.

Among the above results, length of body of the sternum and the total length are more reliable parameters.

- We could differentiate an unknown skeletal remain as **female** if the:
    1. Length of the body of sternum is less than 72 mm.
    2. Breadth of manubrium is less than 48 mm.
    3. Breadth of body of sternum is less than 29 mm.
    4. Sternal index is 70 or above.
    5. Total length is below 119 mm.

Any how, accuracy of the above results are minimal.

Comprehensively, In both Sexes it was evident that all parameters except

length of the manubrium had equivocal area and such area could not be sexed as male or female. This can be noted as a limitation of this study.

- ✦ Fusion of various segments of sternum revealed following findings:
    1. Fusion between the segments of sternal body seems to be a more reliable one. Minimum age of the individual could be 21 years if all the segments of the body of sternum are fused.

    2. Age determination from union of manubrium and xiphoid process with the body is rather unpredictable.

        i. However, if the manubrium and body of sternum are fused, the age of the individual could be more than 35 years in males and more than 43 years in females.
        ii. Moreover, fusion of xiphoid with the body occurs anywhere in between 32 to 60 years irrespective of sex.

This trend of variations in fusion as observed in this study could possibly be due to the influence of nutritional, genetic, hormonal and environmental factors.

- ★ Conclusions derived in the determination of stature are as follows:
    1. In males, length of body of sternum or total length seem to be more reliable.
    2. In females, length of body of sternum could be taken for determination of stature of an individual.
    3. When the sex is not known, length of body or total length could be

used for stature determination.

Totally, determination of stature from length of body of sternum is more reliable in both males and females as well as in the condition where the sex is not determined.

The regression formulae obtained in this study can be used for determination of stature from the length of mesosternum in cases of indigenous people of in and around Tirunelveli, particularly when there are no other suitable means.

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ANNEXURE - 10

PROFORMA FOR DETERMINATION OF SEX, AGE AND STATURE FROM STERNUM

1. Serial No : Date :
2. PM No :
3. Name :
4. Place :
5. Age :
6. Sex :
7. Marital Status :
8. Occupation :
9. Height : cm
10. Weight : kg
11. Nutritional status : Good Moderate Poor Obese
12. History of any injury
    If yes, specify : Yes ☐ No ☐
13. Disease of chest wall
    If yes, specify : Y☐ N☐
14. Evidence of any bony disease
    If yes, specify : Yes ☐ No ☐

<u>Measurements of sternum</u>

1. Length of manubrium :
2. Length of body of sternum :
3. Breadth of manubrium :
4. Breadth of body of sternum :
5. Sternal index :
6. Total length of sternum :
7. Stages of fusion
   a. Manubrium with body : F☐d Not ☐d
   b. Individual segments of body
      First and second : Fused ☐ Not fused ☐
      Second and third : Fused ☐ Not fused ☐
      Third and fourth : Fused ☐ Not fused ☐
   c. Body with xiphoid process : Fused ☐ Not fused ☐

Signature

Name: